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Multi-Disciplinary University Research Initiative (MURI) on Integrated Predictive Diagnostics (IPD)

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LONG TERM GOALS

The long term goal of this coordinated research is to develop smart monitoring systems for military and commercial platforms which will provide enhanced mission effectiveness, reduced maintenance actions, increased system reliability, increased human safety, and reduced lifecycle costs. This research effort is aimed at resolving research issues in diagnosing the current state of a mechanical system and predicting the system's remaining useful life.

RESEARCH COMPONENTS

Sensors and Sensing Systems [Dr. David C. Swanson] — The focus of this research is aimed at establishing robust, smart, self-calibrating sensors for an integrated predictive diagnostics environment. New sensors will be designed, fabricated, and evaluated as part of an end-to-end sensing, processing, intelligence inference process. Initial research has resulted in a new GaAs nanofabricated accelerometer and a system design for a self-calibrating sensor. In addition, prototype sensors have been demonstrated for utilizing magnetic phenomena to observe crack initiation in bearings and gears.

Micro-Mechanical Failure Models [Dr. Digby D. Macdonald] — The focus of this research is to develop an understanding of failure phenomenology which provides a basis for calibrating failure predictive models and the sensing process. Empirical models of fatigue, fracture, and wear will be applied and improved using transitional failure data to model failure migration, safe life extension strategies, and the effects of the environment of failure models. Current research has begun to quantify the effects of hydrogen (e.g., found in hydrocarbon lubricants) on the life span of high strength steel commonly used in DoD weapon systems. Further, a number of experiments have been initiated to collect calibrated data as mechanical components such as gears, bearings, and mechanical structures are driven to failure.

Nonlinear Dynamical Modeling [Dr. Joseph P. Cusumano] — This research is developing a methodology for obtaining state-space-based nonlinear dynamic models of failure progression. The methodology integrates purely empirical (implicit knowledge) and first principles (explicit knowledge). This research utilizes a combination of realistic physical experiments, numerical experiments, physics-based mathematical modeling, and analysis. Analytic modeling will be validated using real data collected on mechanical testbeds. At this time, a general theoretical framework has been developed for predicting failure phenomena.

Signal Processing and Multisensor Data Fusion [Mr. Derek C. Lang] — The signal processing and data fusion research thrust focuses on fundamental advances in signal processing and data fusion technology to improve the detection, classification, and estimation of state variables across the IPD hierarchy for improved diagnostics. Signal processing techniques developed must extract and interpret information from sensors in a high noise environment across the hierarchy of element, component, subsystem, and system levels. Signal processing algorithms are incorporated into a data fusion toolkit which permits rapid implementation of signal processing chains and data fusion techniques. Initial research has analyzed the ability of a wide variety of techniques to characterize sensor data and provide reliable indicators of impending failures. These techniques include time domain, frequency domain, and time-frequency domain algorithms. At this time, several robust methods have been developed to indicate the onset of failure phenomena.

Intelligent Reasoning and Control [Dr. Amulya K. Garga] — This research thrust is aimed at developing reasoning methods to perform automated intelligent integrated predictive diagnostics. This reasoning seeks to make decisions about operational actions, provide warnings to human operators, and perform real-time feedback for low level subsystems to extend the safe life of a system and platform. A general structure has been developed for automated reasoning about condition-based monitoring systems. Quantitative comparisons have been made between fuzzy logic, neural networks, and rule-based reasoning systems. New hybrid implicit/explicit reasoning approaches have been developed.

The research currently being performed under this project has been provided to industry, government, and academic researchers. A special Internet web site (*www.wisdom.arl.psu.edu*) provides access to data, publications, algorithms, and general information about condition-based maintenance. In addition, the project supports researchers at RPI and at the Tennessee State University (a historic Black University). The techniques developed under this effort are being transitioned to USN fleet demonstration via a companion project — the Accelerated Capabilities Initiative for Condition Monitoring.